HEATER ENGINEERED MANAGEMENT SYSTEM FOR HEAT DISTRIBUTION SYSTEMS

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INTRODUCTION

The Army owns just over 4,500 kilometers (2,800 miles) of heat distribution system (HDS) piping according to the FY96 Annual Summary of Operations (Redbook)[1]. HDS supply pipes convey steam or hot water from a central heat plant to the buildings where it can be used for space heating, industrial processes, production of domestic hot water, sterilization, or other processes that require heat. After the heat has been extracted, return piping usually transports the water or condensate back to the central heat plant.

Interruptions in heating service can adversely impact the mission, result in inconvenience and discomfort for personnel, and cause damage to equipment and facilities (such as building plumbing that freezes and bursts). Unfortunately, many of the Army's HDSs are in fair to poor condition and are continuing to deteriorate. This not only decreases their reliability, but also can result in high maintenance costs and high energy losses. (FY96 heat system operating costs totaled $446 million, and maintenance and repair (M & R) costs were $81 million.) High energy losses in HDSs will make it more difficult to meet the requirements of Executive Order (EO) 12902, AEnergy Efficiency and Water Conservation Act Federal Facilities@.[2] Using FY85 statistics as a baseline, this EO requires federal facilities to reduce energy usage by 20% by the year 2000 and 30% by 2005.

Several general trends contribute to the problems with HDSs:

- Operation and maintenance (O & M) budgets are decreasing.

- Utility projects are difficult to Asell@ to budget decision makers because the systems are Aout of sight-- out of mind@ until there is a problem.

- Manpower is decreasing due to reductions in force.

- AInstitutional knowledge@ about installation facilities is being lost as experienced workers retire or are laid off.

These trends have forced many facilities engineers into a mode of crisis management (i.e., Aif it isn=t broken, don=t fix it@). This is usually not the most cost-effective way of doing business in the long term. Unfortunately, the general trends outlined above are not likely to change very much in the near future.

ENGINEERED MANAGEMENT SYSTEMS

The fact that Army facilities engineers are facing the problems outlined above implies that they need tools to (1) help them persuade decision-makers to fund infrastructure repair and rehabilitation projects, and (2) help them allocate those resources where they will produce maximum results. The U. S. Army Construction Engineering Research Laboratories (USACERL) is developing a family of such tools called Engineered Management Systems (EMSs). EMSs are being developed for a variety of facilities at Army installations including transportation systems, utility systems, and buildings.

All of the EMSs follow a similar, proven approach to facilities management. Each EMS contains several common elements. These are (1) inventory, (2) inspection, (3) condition assessment, (4) condition prediction, (5) maintenance and repair (M & R) requirements identification/ work planning, and (6) project formulation. These elements will be defined and illustrated in the following sections describing the HEATER EMS.

EMS software specifications have been developed to ensure that all EMSs have a similar Alook and feel@ to the user. This minimizes training costs and increases user satisfaction. The specifications are based on object-oriented programming concepts. Development costs are reduced using modular software architecture, standardized communication protocols, and reusable software components.

HEATER OVERVIEW

The HEATER EMS includes systematic procedures for identifying and prioritizing HDS maintenance and repair needs, as well as for quantifying the consequences of not performing the recommended actions. HEATER includes low-, medium-, and high-pressure steam distribution systems and condensate return, as well as low- and high-temperature hot water distribution systems. HEATER development is being given high priority because of the high payback on heat distribution system maintenance and modernization. HEATER is being developed in the Visual Basic programming language and utilizes Microsoft Access as the database manager.

HEATER incorporates Washington State University=s HeatMap program to provide flow, pressure, temperature, and heat loss analysis for the HDS. HeatMap is used to design new distribution systems, model the operation of existing systems, and provide AutoCAD-based system maps. HEATER is therefore a comprehensive HDS management tool that covers design, operation, maintenance, and repair. A schematic of the HEATER system is shown in Figure 1.

HEATER is currently being implemented at Ft. Jackson, SC. Data and results from the Ft. Jackson work will be used to illustrate the features of the HEATER system.

FT. JACKSON TEST SITE

Ft. Jackson, SC is served by three central energy plants (CEP). CEP1 is located in Building 2288 and produces medium temperature hot water at a pressure of 1370 kPa (200 psig) and a temperature of 115EC (240EF). The distribution system from CEP1 consists of both shallow concrete trench-type piping and direct-buried conduit-type piping. Most of the CEP1 distribution system was installed in 1986.

CEP2 is located in Building 4333 and produces high temperature hot water at a pressure of 2415 kPa (350 psig) and a temperature of 196EC (385EF). The distribution system from CEP2 consists of both shallow concrete trench-type piping and direct-buried conduit-type piping. Most of the CEP2 distribution system was installed in 1987.

CEP3 is located in Building 1699 and produces medium temperature hot water at a pressure of 1370 kPa (200 psig) and a temperature of 115EC (240EF). The distribution system from CEP3 consists mostly of shallow concrete trench-type piping with some direct-buried conduit-type piping. Most of the CEP3 distribution system was installed in either 1988 or 1992.

HEATER INVENTORY

The first step in maintenance management is to determine what needs to be managed. This is done by preparing an inventory, which is a physical description of the facility system that is being managed. An inventory answers questions such as AWhat facilities do I have?@ and AHow much/ how many are there?@ To create the inventory, the facility system is broken down into subcomponents or sections for which M & R decisions will be made. Descriptive data are then collected about each section or subcomponent. This information typically does not change with time (unless the section is replaced) and may include attributes such as location, size, material of construction, and date of installation. A map may also be included as part of the inventory.

For HDSs, the inventory consists of pipe sections and nodes. Nodes may be further subdivided into manholes and branch takeoffs. The first step in implementing HEATER is to define the HDS in terms of these components. This process begins with an AutoCAD map (.DWG file) of the HDS. The pipes and nodes are defined first in the HeatMap program. Each manhole and branch takeoff is given a unique node identification that consists of 1 to 4 alphanumeric characters. The pipes that connect the nodes are also given identifiers that may have up to eight characters. Figure 2 shows a portion of the Ft. Jackson HDS from CEP2 as represented in HeatMap with the pipes and nodes identified.

The next step is to collect and enter descriptive data about each item in the inventory. The HeatMap program automatically measures and stores the length of each pipe. It allows the user to input other fundamental data about the pipes, such as their diameter and estimated heat transfer coefficient. It stores the information that is needed for flow, pressure, and temperature calculations throughout the system.

Storage of the detailed pipe and node information that is required for maintenance is done in the HEATER databases. When a new HEATER database is created, the basic inventory information that was created in HeatMap is imported into HEATER.

The main HEATER screen is shown in Figure 3. The screen is displaying Ft. Jackson=s CEP3. The HEATER screen is divided into three sections. The section on the left displays a GIS-based map of the HDS. The section in the upper right displays a tree-type inventory navigation tool (similar to the Microsoft Windows 95 Explorer). The section in the lower right displays the screen for the task that the user has selected, such as inventory, inspection, or prediction modeling.

Once the HEATER files have been created, the user may enter inventory data about each pipe in the distribution system. The user first selects a pipe by pointing to it on the map or by pointing to its name on the Atree@ navigation tool. The user then enters data about the pipe section. (One record is entered for each pipe). Each section may have one or more expansion joints, steam traps, valves, pipe supports, and/or pipe anchors associated with it. Users may enter data about these subcomponents associated with the currently selected pipe section by clicking on the appropriate tab on the screen. For example, Figure 4 shows the screen that appears when the user clicks on the APipe support@ tab. The user would then enter information about the pipe supports that are associated with the pipe of interest. Using tabbed screens to display data enables a large amount of information to be displayed on a single screen.

The next step is to enter additional information about the system manholes. As before, the user selects the manhole or node of interest from the map or from the navigation tool. One record is entered for each manhole (Figure 5). Each manhole typically has many subcomponents. These may include ladders, sump pumps, high water alarms, internal piping, pipe supports, pipe anchors, expansion joints, steam traps, valves, wall penetrations, and a cover. Users may enter data about the subcomponents associated with each manhole by clicking on the appropriate tab on the screen.

HEATER INSPECTION

The inspection is a consistent, repeatable procedure for gathering the data needed to determine the condition of each item in the inventory. The procedures are designed so that the results are as independent as possible from the subjective judgements of the individual inspector.

Inspection usually involves the documentation of Adistresses@ (defects or indicators of problems), the severity of the distress, and the quantity of the distress. EMS inspections may involve in-situ non-destructive testing, visual inspections, and/or laboratory testing.

HEATER has a two-stage inspection process. The network-level inspection includes both visual and simple field testing procedures. It flags components where M&R is required, provides a rough estimate of the condition of the system components, and identifies components that require more extensive inspection before their condition can be determined. For example, the network level inspection distresses for manhole end plate assemblies are shown in Table 1.

Project-level inspection includes more expensive and/or complicated techniques to establish the condition of components that cannot be readily evaluated with network level techniques. For example, conduit pressure testing is a project-level technique.

A network-level inspection was performed at Ft. Jackson. The results revealed severe degradation in some areas of the CEP2 distribution system.

HEATER CONDITION ASSESSMENT

Condition assessment is the process of interpreting the results of the inspection. In most EMSs, this is done by means of a condition index (CI), which is a quantifiable, repeatable measure of facility health that is calculated from the inspection data. The CI is expressed on a scale of 0 to 100, with 100 representing a facility in new, perfect condition and 0 representing a facility that is completely failed. The CI provides a common language for comparison of diverse facilities.

HEATER contains CIs for the various HDS components. Condition indexes are assigned based on the results of the inspection. Table 1 shows an example of this, again using the manhole end plate assemblies as an example. Inspection and condition index data may be entered into the HEATER database for pipes, manholes, and their associated subcomponents. Figure 8 shows the manhole inspection data entry screen.

In addition, the user may also perform a HeatMap analysis of pressure, flow, temperature, and heat loss. Figure 7 shows a partial printout of the HeatMap results for CEP3.

HEATER CONDITION PREDICTION

Condition prediction is a method for forecasting the future condition index of items in the inventory so that repair and replacement decisions may be timed correctly.

Some EMSs may provide a set of prediction models that have been developed from a statistically significant number of data points, while others may provide users with the tools to build installation-specific models using their own data.

Very general condition prediction models have been developed for each type of HDS based upon case studies. The models predict the degradation of condition versus time. Further development on the models is planned so that the effects of soil chemistry, temperature, and other influencing factors can be incorporated. HEATER also includes the EMS shared tool for Afamily curve@ prediction modeling, which allows users to build their own prediction curves from installation-specific data (Figure 8). Models may be built from any subset of data. For example, users may wish to calculate a prediction model for pipes of a specific type or material (such as direct buried piping with a steel casing).

HEATER M & R REQUIREMENTS IDENTIFICATION AND WORK PLANNING

M & R requirement identification is a procedure for determining the work that needs to be done to the facility system based on the findings of the previously described elements. Most EMSs can provide both annual and long-range work plans that are constrained either by budget or by minimum acceptable condition.

Based upon the findings of the condition assessment and prediction, the user can generate maintenance and repair requirement lists. HEATER allows users to analyze various maintenance options and determine which one will be the most cost effective.

To illustrate the use of HEATER in determining the most cost-effective course of action, options were analyzed for a part of the Ft. Jackson distribution system that is served by CEP2. The part that was analyzed is comprised of 316 feet of 8-inch diameter piping, 290 feet of 4-inch diameter piping, and 365 feet of 1-inch diameter piping. The inspection and condition assessment revealed that these pipes were severely deteriorated and had condition indexes between 10 and 30. Option #1 was to do nothing now, but budget for replacement in 5 years. Option #2 was to replace all of the deteriorated pipe immediately with a concrete shallow trench system. For both options, HEATER was used to forecast the condition of the pipes during the next 5 years and to estimate the amount of heat that would be lost during that time from the deteriorated pipes. The calculations showed that an additional $85,000 worth of heat would be lost if the replacement was deferred for 5 years, and that it would be more cost effective to replace the pipes immediately.

THE UTILITIES EMS SUITE CONCEPT

HEATER is a part of the Utilities EMS Suite. The suite will include: (1) "component" utility EMSs and (2) a set of shared utility analysis tools. Component EMSs are EMSs for specific utility systems, such as HEATER. Shared tools refer to analytic procedures that are applicable to more than one utility and can be used by more than one component utility EMS. For example, the method for cathodic protection (CP) evaluation is the same for all utilities, therefore it is much more efficient to develop one software tool for CP analysis that will interface with all component EMSs (instead of developing a separate CP analysis tool for each EMS).

To help readers better understand the Utilities EMS Suite concept, the suite may be compared with an integrated applications suite such as Microsoft Office. Microsoft Office includes several component programs: a word processor (Word), a spreadsheet (Excel), presentation graphics (PowerPoint), and a database manager (Access). Each of these component programs can be purchased and used as a stand-alone application. They also may be used together. The user interfaces of the programs are so similar that if you know how to use one of them, you can learn to use any of the others very quickly. These individual, yet interoperable programs can be compared to the individual component Utilities EMSs such as HEATER. Microsoft Office also includes tools that may be used in several (or all) component programs--the Spell Checker, for example. These tools can be compared to the Ashared tools@ in the Utilities EMS Suite.

REFERENCES

1. *Department of the Army Directorates of Public Works Annual Summary of Operations-- Fiscal Year 1996*, (Department of the Army, 1997).

2. Executive Order (EO) 12902, AEnergy Efficiency and Water Conservation Act Federal Facilities@ (1994)